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# Black-and-White Textures for Visualization on E-ink Displays

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## ABSTRACT

We introduce a design space for black and white textures and the prototype of a design tool that supports designers to explore different black-and-white textures for visualization on e-ink displays. We are currently working on an exploratory online study in which experts will design four different categorical encodings using different types of black-and-white textures.

**Index Terms:** Human-centered computing—Visualization—Visualization systems and tools

## 1 INTRODUCTION AND BACKGROUND

E-ink displays are now widely used on devices such as smartwatches, electronic shelf labels, and e-readers. E-ink displays are popular for their low power consumption, relatively low cost, and reduced eye strain when reading. As a tradeoff, they have only a few colors and low refresh rates. While research and development for e-ink displays has increased the number of displayable colors, most e-ink displays are still black-and-white or have only a few additional colors that could be used for visualization. Yet, many types of charts require color hue or saturation to encode quantitative or categorical data. With our research we want to understand how we can effectively visualize data in the absence of color. We explored several strategies and, inspired by historical practice, focused on texture encodings.

We first explored alternatives to the use of color hue or saturation in data graphics, then derived a design space of black-and-white texture dimensions, and finally designed a tool to explore different types of textures to encode categories on bar and pie charts. Our ultimate goal is to study the features of black-and-white textures to come up with guidelines that help designers build beautiful and effective data visualizations specifically for e-ink displays.

Throughout our discussion we use the term *texture*, following definitions in computer graphics where a texture is a 2D image applied to (the surface of) a graphical object that is potentially repeated multiple times through some form of tiling. Specifically, here we refer to a texture as a tiling pattern that is characterized by the type of shapes we use as part of the pattern (lines, dots, . . .), the density of the shapes, their size, orientation, etc.

The challenge of a limited number of displayable colors has been present in the use of virtually all printing technology as well as the early days of computer screens. Many historical examples exist that showcase beautiful and stunning data graphics, drawn without color. Brinton [2, p.32], e. g., shows an over 100 year old example of a heatmap (Fig. 1) that uses black-and-white textures. Bertin’s *Semiology of Graphics* [1] discusses textures extensively, for points, lines, and areas and with various graphical properties. Bertin uses the term *texture*, however, to refer to differences in density applied to a shape<sup>1</sup> (e. g., ■ vs. ■■■) and the term *pattern* to instead refer to differences in shapes applied to a mark (e. g., ■■■ vs. ■■■■). Here, we use a slightly different terminology as outlined above but Bertin’s advice on the use of his visual variables *texture* (*density*), *orientation*, and *shape* was valuable for our work. Both Tufte [7] and Bertin [1]

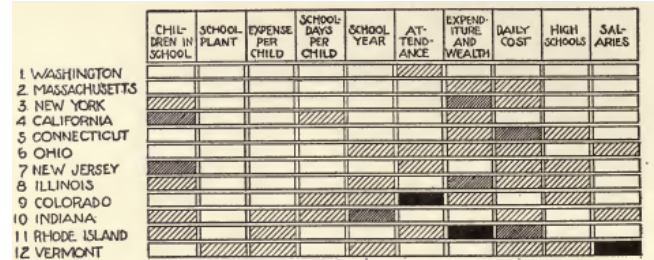






Figure 1: Rank of US states in ten education features, 1910. Taken from [2, p.32], trimmed to 12 states. Picture in the public domain (©).

warn that textures may produce Moiré vibrations and Tufte [7] even goes so far to say that they should be avoided altogether.

Some examples of using Tufte’s and Bertin’s advice for black-and-white visual representations exist, such as Perin et al.’s Bertifier [6]. In computer graphics, black-and-white textures are also used, usually in the sub-field of non-photorealistic rendering such as for stippling [3, 4] or hatching [5]. Here the goal is, however, the replication of traditional drawing techniques that represent shading and material properties, as opposed to data representation like in our case.

## 2 TEXTURE FEATURES

In data visualization, textures can be applied to both the stroke  and the fill  of a data-representing mark. We discuss textures as repeated (tiled) shapes, such as lines  or dots . Shapes can be applied both to the fill of a mark or along its outline. We detail the texture properties we found useful to configure black-and-white textures with examples in Table 1. In particular, we considered:

**Density:** how closely packed shapes inside the texture are while maintaining the same black-to-white ratio (value). That is, if more black shapes are to cover a certain mark, they will be reduced in size to maintain the same black/white ratio.

**Shape Size:** the size of the shape inside the texture. Increasing the size while leaving density the same will result in a change in value (black/white ratio). Changing size and density together allows keeping the black/white ratio (value) the same.

**Orientation:** orientation/angle of shapes inside the texture

**Shape type:** shape type used inside the texture (line, dot, square, . . .)

**Grouping:** This texture property is not a visual variable listed by Bertin. It describes how shapes are placed on a mark. For example, in a regular grid, with an offset, randomly etc. Changes in grouping result in a visually different texture but do not change overall value, and—depending on the grouping—also not the perception of density.

From the descriptions of texture parameters it becomes clear that choosing correct parameters for visualization is not a trivial task. Which we further explored for categorical data.

## 3 VISUALIZING CATEGORICAL DATA FOR BLACK AND WHITE TEXTURES











Past work in visualization [1] and in particular computer graphics [4, 5] includes advice on how to generate textures with a given value encoding that could be used for the visualization of ordered

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<sup>1</sup>To be precise: To Bertin, changes in texture only affect the number of separable marks in an area and not the overall value.

Table 1: Texture properties with examples and characteristics with lengths for density, orientation, and shape as recommended by Bertin [1]. Recommendations on density, shape, orientation use for categorical or ordered (incl. quantitative) data also follows Bertin.

Texture property	Example Fill	Example Stroke	Length	Categorical Data	Ordered Data
Density			2–5	✓	✓
Shape Size			4–5	✗	✓
Orientation			2–4	✓	✗
Shape type			large	✓	✗
Grouping			small	✓	✗

data. Little advice, however, exists on the use of different shapes, orientations, and grouping for the encoding of categorical data, which led us to explore the replacement of color hue with black-and-white textures. We first attempted our own designs to replace color hues in common visualizations such as area charts, choropleth maps, heatmaps, or bar- and pie charts to observe the effects of changing categorical texture parameters. Fig. 2 highlights two non-optimal designs that highlight the non-trivial choices to make when replacing color hue with textures. The left image, for example, shows that changes in value happen quickly when changing the shape, for example from dots to lines or crosses. The right image illustrates that certain orientations can interfere with the perception of horizontal (or vertical) lines. In addition, not every shape is suited to thin and long areas; the cross on the top series on the left is almost invisible. Lines on the left and right begin to produce the vibratory effects both Bertin [1] and Tufte [7] warn about.

Following our investigations, we formulated several concrete research questions for black-and-white textures for categorical data representation. We use the word “effective” below to refer to multiple possible benefits such as data reading correctness, memorability, aesthetics etc.—none of which have yet been explored in depth.

**Marks:** Are certain textures better suited to specific marks (rectangles, circles, arbitrary shapes of different dimensions)?

**Shapes:** Are textures with data-relevant shapes more effective than arbitrary shapes?

**Shape similarity:** Is it more effective to use textures of similar shapes that vary in orientation or grouping, or should textures of different shapes be used?

**Perception:** How many differences in one texture property can be meaningful distinguished?

**Interplay of density and size:** To which extent do changes in density or shape size affect the effectiveness of a texture?

#### 4 STUDYING TEXTURE DESIGN

We built an online tool (Fig. 3) that allows us to more formally experiment with texture parameters for bar and pie charts to explore some of these questions. Our tool uses SVG pattern fills and their parameters to realize textures and is compatible with D3 and other SVG visualizations. Realizing the above outlined texture parameters in the tool was not trivial. First, allowing people to choose density, while ensuring that the black/white ratio on each mark remains the same, was not possible with SVG patterns. Essentially this would have meant to analyze the applied texture on a mark by sampling its contribution of black vs. white to an area, while also taking possible perceptual effects of the size of shapes into account. Instead, we realized density by controlling the SVG pattern width/height. Shape size is manipulated by setting the width/height of the SVG shape embedded in the pattern. This meant that both density and size affect each other; high densities are only possible with small shapes,

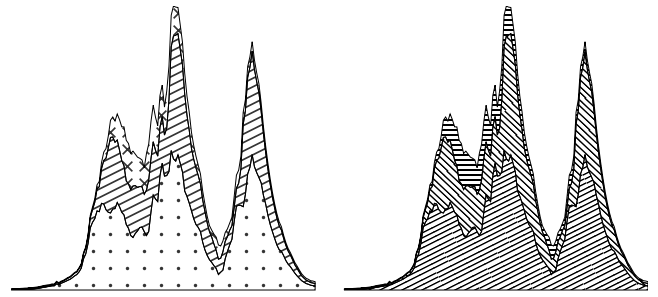


Figure 2: Experiment for replacing categorical color in an area chart.

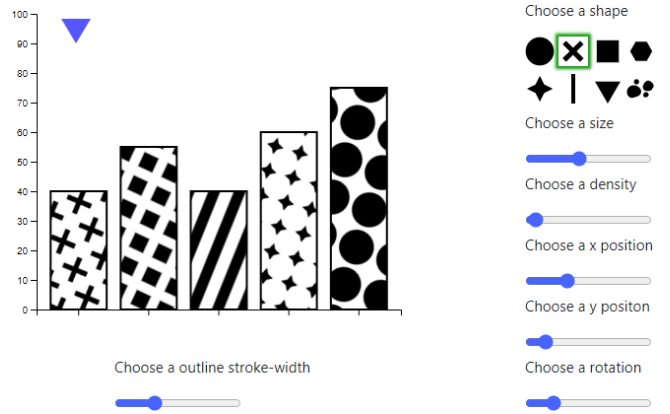


Figure 3: Screenshot of our tool for testing texture parameters.

otherwise the images embedded in each pattern are cut off. To allow us to use different grouping patterns we introduced an angle of rotation for the complete pattern (rather than for individual shapes). For bar charts we also needed to add controllers to shift the texture in x- and y-direction to avoid unaesthetic white space introduced with large densities or small shape sizes. We currently offer one simple dataset based on counts for fruits and two types of texture shapes: iconic representations of fruits and more abstract shapes (Fig. 3).

Our next goal is to study how visualization designers apply textures to these two simple representations. In particular, we are interested in studying the different use of iconic vs. general patterns. We plan to ask visualization designers to participate in a small texture generation study and then analyze the results, before we start addressing some of the other research questions about textures that we outlined above.

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